Transactions of Illinois Academy of Sciences
(1982), Volume 75, 1 and 2, pp. 15-27

Benthic insect colonization of introduced substrates in the Sangamon River, Illinois

Richard B. Shepard[1]
Department of Ecology, Ethology, and Evolution
University of Illinois
Urbana, Illinois 61801

ABSTRACT

Experiments were performed in the Sangamon River, east-central Illinois, to determine the optimum substrate and location within the stream channel to yield the most information per sample concerning community structure. A 31-day colonization experiment resulted in different aquatic insect communities on dowel bundles, barked logs, and debarked logs. Debarked log faunas were dominated by dipterans, with ephemeropterans next most abundant; the reverse was true for both barked logs and dowel bundles, both of which contained crevices which were refugia and sediment traps. A 3-week colonization experiment compared communities on dowels and logs in three locations across the stream. Ephemeropterans comprised 65 to 88% of the faunas, coleopterans were next most abundant (ca. 14%) while plecopterans, trichopterans, and odonates were all small percentages of the total numbers. Samplers near center channel provided suitable habitat where none was before and were most reasonably colonized by drift; samplers near each bank could have been colonized by swimming individuals. Densities were low compared with other midwestern streams, possibly as a result of insufficient habitat (although short colonization times underestimated potential densities). Control of community structure on these substrates appeared to be due more to abiotic variables than to biotic interactions.

INTRODUCTION

Lotic insects are generally more abundant on firm substrates than on sand or finer particles (Cummins 1966). In the upper reaches of the Sangamon River, much of the bottom consists of mud and clays with occasional longitudinal submerged sand bars; this substrate is typical of many Illinois streams draining agricultural watersheds. A study was planned to examine microdistribution and population dynamics of benthic insects in such systems for comparison with data from faster-flowing streams with firmer substrates. Preliminary sampling from autumn

---

[1] Present address: Department of Biology, Idaho State University, Pocatello, Idaho 83209

1974 through spring 1975 along a 250 m segment of the river revealed very patchy distribution of the insects: they were collected only where solid substrates were available (exposed roots and downed trees along the banks and on exposed logs in the streambed). These findings led to questions concerning the techniques most appropriate for sampling these populations.

During summer 1975, two experiments were performed to evaluate the relationship between different types of wood substrates, colonization time, and position in the stream channel on the numbers of individuals and species of benthic insects collected. The model upon which comparisons were made was the logseries distribution and its associated parameters (Fisher *et al.* 1943, Shepard unpublished manuscript). Thus, although the data set was too small to test general ecological theories of population distributions in patchy habitats or of island colonization it was large enough to test the hypothesis that similar communities will develop on different substrates in different positions over the same time span.

STUDY AREA

The study site (Fig. 1) was a 250 m segment near the headwaters of the Sangamon River at an elevation of about 250 m a.s.l., located 6.9 km northeast of Mahomet, Champaign County, Illinois (T. 21N, R. 7E, Sec. 23, Gibson City 15 min quadrangle, U.S.G.S.); 40° 15′ 52″ North, 88° 22′ 41″ West. At the time of these experiments, the study site was about 30 m wide and up to 1 m deep. Banks were mostly clay; heavy riparian vegetation (both trees and shrubs) grew down to the water's surface for almost the entire length.

Water temperature was greater than 20° C with dissolved oxygen concentrations of 4 to 8 mg/l. Reaeration was low as current velocities were very slow and turbidity was moderate to high. Table 1 summarizes the physicochemical conditions measured during the second experiment.

METHODS AND MATERIALS

Experiment 1:

On 13 June 1975 two sets of samplers were set in the water column about 1 m from the east bank and about 5 m downstream from the north end of the study area. Each set consisted of a log with intact bark (30.5 cm long × ca. 7.5 cm diameter), a similarly sized log stripped of bark, and a bundle of 7 hardwood dowels (each 30.5 cm long × 2.5 cm diameter) held together with a stainless steel clamp. Thin nylon cord held the samplers ca. 30 cm above the sediment between a float and an anchor. After 31 days each sampler was removed in a fine-meshed net, placed in a separate plastic bag, and transported to the laboratory. Logs and individual dowels were scrubbed in a pan of water to remove all invertebrates which were subsequently identified and counted. Numbers/m^2 on the 3 substrates were compared by Analysis of Variance (Sokal and Rohlf 1969).

Temperature and dissolved oxygen were measured with a YSI model 54 meter, and water velocity with a Gurley no. 625-F pigmy current meter. A 250 ml water sample was returned to the laboratory for turbidity determinations (Hach model 2100A turbidimeter).

Experiment 2:

On 18 July 1975 substrate sets (3 per site) were placed at 3 locations across the channel. Each set consisted of 3 barked logs and 3 dowel bundles suspended just below the surface using anchors and floats. The sites were located on a diagonal line from the east bank to the west bank near the middle of the study area. Water depth was 30 cm on the east side, 100 cm near center channel, and 80 cm on the west side.

At the end of 1, 2, and 3 weeks samplers (3 replicates/substrate type) were recovered from each site and examined for macroinvertebrates as before. This series was analyzed for both spatial and temporal patterns of colonization. Physicochemical data were gathered as in experiment 1.

RESULTS

Experiment 1:

A total of 19 different taxa was collected from the 3 sets of substrates (Table 2). Debarked logs had fewest individuals and species while dowel bundles had the most of each (but proportionally fewer individuals than barked logs on an areal basis). Of the six orders considered, two (Plecoptera and Trichoptera) were not found on debarked logs; the plecopteran, *Perlesta placida*, was collected only on dowels. Diptera dominated the fauna on debarked logs (47.6%), closely followed by Ephemeroptera (38.5%). The reverse was found on the other two substrates where Ephemeroptera were most abundant on barked logs (61.5%) and dowels (53.0%) with Diptera much less numerous (23.4% and 30.7%, respectively). Coleopterans were moderately abundant on all three types of substrate, averaging about 12.5% of the faunas; both odonates and trichopterans were rare (< 3%).

On all three substrates microhabitat preferences were exhibited by the organisms as reflected in their relative abundances. An R x C Test of Independence of taxa and substrate type (Sokal and Rohlf 1969) was significant ($P < 0.001$) indicating rejection of the null hypothesis that these two variables were independent.

Classification of taxa into functional feeding categories (Merritt and Cummins 1978) revealed three groups present on debarked logs and five groups present on each of the other two substrates. Collector-gatherers were dominant on all three substrates (52.4% on debarked logs, 69.8% on barked logs, and 63.3% on dowel bundles) and miners comprised the next most abundant group (40.5% on debarked logs, 23.5% on barked logs, and 28.4% on dowels). Predators accounted for 7.1% of the fauna on debarked logs, 1.9% on barked logs, and 3.8% on dowels. Scrapers and shredders were absent on debarked logs, but comprised 2.9% and 1.9% (respectively) on barked logs and 2.0% and 1.5% (respectively) on dowels.

Calculation of an index of community structure (Fisher *et al.* 1943, Shepard unpublished manuscript) yielded a value for the dowel bundles ($\alpha = 3.03 \pm 0.36$) greater than either type of log; there was no significant difference ($P > 0.05$) between barked logs ($\alpha = 1.94 \pm 0.30$) (Fig. 2). Because this structural index is based on a logseries distribution of individuals among taxa, it reflects the influence of biotic and abiotic factors upon the composition of the biota by evaluating species richness relative to total numbers of individuals.

Physicochemical conditions over this period remained fairly constant. On both dates the water was warm (~ 20° C) with negligible current (< 0.5 cm/sec); dissolved oxygen was not limiting (7.8 and 8.6 mg/l) and turbidity was moderate (34 and 21 FTU).

Experiment 2:

During this portion of the study, collections yielded the equivalent of 10,000 individuals/m^2 distributed among 14 species (Table 3). Dowels were colonized by slightly more than half the total numbers (53.5%) for the entire experimental period and increased by 116% from the first to the third week. Percent change in numbers/m^2 from one week to the next increased from 44.6% to 49.3%; greatest total numbers were found in center channel (site 3) and fewest along the east bank (site 1). In contrast, numbers/m^2 on logs increased by only 49% over the three weeks and, on a weekly basis, slowed from a 25.0% increase between the first two weeks to a 19.3% increase over the last two weeks. Logs along the east bank had the greatest numbers of individuals while those along the west bank had the fewest.

Over each of the variables (substrate type, position, and time) the fauna was dominated by Ephemeroptera: 65.4% on logs at site 1 to 88.2% on dowels at site 2. The coleopteran *Macronychus glabratus* was next most abundant (averaging about 14% of total numbers), while plecopterans, trichopterans, and odonates were each a very small percentage of the total. Relative abundances of functional feeding groups followed the ordinal abundance patterns, i.e., most organisms were gatherers or scrapers feeding upon fine particulate organic matter while shredders, filterers, and predators were few.

Comparisons of numbers/m^2 by time available for colonization, substrate type, and position in the stream channel using a Multiway Test of Independence (Sokal and Rohlf 1969) resulted in rejection of the null hypothesis that the variables were jointly independent ($P < 0.001$). Calculation of this G-statistic for all possible pairs of variables revealed that they were all associated.

The α index of community structure was always lower than in the first experiment. In general, dowels had higher values of α than did logs, but both temporal and spatial patterns were highly variable (Fig. 3). Not unexpectedly, maximum values occurred after 21 days' colonization time when logs along the west bank and dowel bundles near center channel were virtually identical. Because values tended to increase with time, allowing substrates to colonize longer may have resulted in reduced differences observed in the two experiments. Relative similarity of population assemblages on different substrates was determined for both spatial and temporal patterns (Fig. 4) using Mountford's (1962) index based on α. Most similar were the faunas on logs and dowels near the east bank and logs in the center. Both substrates along the west bank clustered together and were distinct from all the others. Temporally, the faunas on 7-day dowels, 21-day logs, and 21-day dowels all grouped together with very high similarity. Seven-day logs and 14-day dowels clustered separately and were less similar to the others. No subcluster was significantly different ($P > 0.05$) from the others.

Of the four physicochemical variables measured, current velocity and turbidity fluctuated more than water temperature or dissolved oxygen (Table 1). When numbers/m^2 on each type of substrate each week were regressed (least squares method) on each variable some significant relationships were found (*i.e.*, the coefficients of determination were greater than 0.90), but without any consistent patterns. These relationships reflect the importance of abiotic variables in influencing numerical size of the populations. Lack of consistent patterns could have resulted from high variability in these factors or from a limited data set.

DISCUSSION

The hypothesis that similar population assemblages develop on different substrates or in different positions within the stream channel was not supported by either experiment in this study. Several factors probably account for the substrate differences: wood type, degree of conditioning, and surface complexity (availability of refugia). Both barked and debarked logs were cut from the same branches which had been lying on the floodplain long enough to have acquired microbial decomposers. Hardwood dowels had not been similarly preconditioned before use, but appeared to have rapidly gained fungal colonizers. While these decomposers were not investigated, it is possible that qualitative differences (based upon length of colonization time) provided preferred food resources for scrapers on the dowels. Surface topology can provide protection from predators which were, in that part of the Sangamon River, primarily centrarchid fishes. Dowel bundles had deep crevices where adjacent dowels met along their lengths, and appeared to provide deeper relief than did bark roughness.

Location of substrates across the channel resulted in different faunal assemblages, perhaps because the channel width was too great and current velocity too slow to allow much drifting from one location to another. Substrates located near each bank were readily accessible to organisms on debris along the water's edge, while substrates near center channel could only have been colonized by drifting organisms; preliminary qualitative sampling over the previous 9 mos yielded only a single heptageniid nymph from sediments further than 1 m from either bank.

Regardless of location, dowels collected much more sediment than either barked or debarked logs, although the latter two substrates also became well coated with sediment. Predominance of collector-gatherers was a reflection of the abundance of fine particulate organic matter. Position of substrate in relation to accumulation of sediments is important in this type of midwest stream as Nilsen and Larimore (1973) found in a study of the Kaskaskia River, Illinois. They found that horizontal logs collected and sloughed sediments much more readily than did logs placed vertically. In the present study, almost all natural log habitats were oriented horizontally so the introduced substrates were placed in the same manner.

Faunal abundance was low relative to other midwestern streams. Maximum densities were about $10{,}000/m^2$ in this segment of the Sangamon River compared with approximately $100{,}000/m^2$ in the Kaskaskia River (Nilsen and Larimore 1973) and approximately $30{,}000/m^2$ in the Chippewa River, Michigan (Litke 1978). Although the Sangamon appeared very turbid, measured values were similar to those in the Kaskaskia, so this was probably not a limiting factor. Two possible explanations for the low abundances are colonization time and amount of suitable habitat. Coleman and Hynes (1970) found that their substrates required more than 28 days to reach steady-state (*i.e.*, pre-disturbance) densities. Nilsen and Larimore (1973) found maximum density was reached only after 5 to 6 weeks, and Shaw and Minshall (1980) found that more than 6 weeks was required for full colonization. Availability of suitable habitat was probably the most important limiting factor in the Sangamon River, as most of the streambed was highly unstable silts and clays and, as mentioned above, macroinvertebrates were found only on downed logs and roots exposed along the banks. Unlike the Kaskaskia River which had numerous debris accumulations generated both by logging and by tree fall from Dutch elm disease, there were relatively few stable logs in the study area. Provision of suitable habitats where none had previously existed (*e.g.*, near center channel) resulted in colonization comparable to samplers nearer the banks. Mayflies, in particular, could detect presence of a suitable habitat and would respond, in the laboratory, by swimming across a large pan to reach dowels inserted at the other end. The same sort of responses to physical habitat cues were observed for predatory stream insects by Peckarsky and Dodson (1980).

An important consideration in any study of stream benthos is the use of a sampling technique appropriate to the ecosystem and purpose of the investigation. It is convenient to use the same type and size sampler as others have for better comparison of results. The nature of the streambed and distribution of insects in the study area necessitated use of wooden samplers rather than baskets (or trays) with rocks, or nets on frames, so as to more closely mimic available habitats. Differences in type of substrate and their location within the channel led to development of distinct communities. This pattern would most likely have been different in autumn (when leaf fall contributes large amounts of allochthonous organic matter) or winter (when the river floods and may increase tenfold in width) but, overall, demonstrated the control of abiotic factors in the distribution and abundance of benthic insects in upper reaches of the Sangamon River.

ACKNOWLEDGMENTS

Drs. W.U. Brigham and J.D. Unzicker of the Illinois Natural History Survey provided guidance and taxonomic assistance during this study. Drs. W.U. and A.R. Brigham allowed access to the study area through their property and permitted me to store equipment there. A.R. Brigham, W.U. Brigham, R.T. Litke, G.W. Minshall, and J.D. Unzicker read and made helpful comments on early drafts of this paper. Partial funding was provided by a grant in aid of research from Sigma Xi, The Scientific Research Society.

LITERATURE CITED

Coleman, M.J. and H.B.N. Hynes. 1970. The vertical distribution of the invertebrate fauna in the bed of a stream. Limnol. Oceanogr. 15:31-40.

Cummins, K.W. 1966. A review of stream ecology with special emphasis on organism-substrate relationships. Pymatuning Lab. Ecol. Spec. Publ. No. 4:2-51.

Fisher, R.A., A.S. Corbet, and C.B. Williams. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. J. Anim. Ecol. 12:42-58.

Litke, R.T. 1978. An investigation of stream continuum theory on the Chippewa River, north of Lake Isabella in Isabella County, Michigan. Unpublished M.S. thesis, Central Michigan University, Mt. Pleasant. 103 pp.

Merritt, R.W. and K.W. Cummins, eds. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publ., Dubuque, Iowa. 441 pp.

Mountford, M.D. 1962. An index of similarity and its application to classificatory problems, pp. 43-50. In: P.W. Murphy, ed. Progress in soil zoology. Butterworth & Co., London.

Nilsen, H.C. and R.W. Larimore. 1973. Establishment of invertebrate communities on log substrates in the Kaskaskia River, Illinois. Ecology 54:366-374.

Peckarsky, B.L. and S.I. Dodson. 1980. An experimental analysis of biological factors contributing to stream community structure. Ecology 61:1283-1290.

Shaw, D.W. and G.W. Minshall. 1980. Colonization of an introduced substrate by streams macroinvertebrates. Oikos 34:259-271.

Sokal, R.R. and J.F. Rohlf. 1969. Biometry. W.H. Freeman & Co., San Francisco. 776 pp.

Table 1. Measured physical and chemical variables at each site during the duration of experiment 2.

Date	Site	Temperature (°C)	Current (cm/sec)	Dissolved Oxygen (mg/l)	Turbidity (FTU)
18 July	East	24.7	8.0	7.8	19.5
	Center	24.6	12.0	8.1	37.5
	West	25.0	8.0	8.2	27.0
25 July	East	23.0	10.0	7.7	22.5
	Center	25.1	10.0	7.7	42.0
	West	24.9	< 0.5	7.5	39.5
1 August	East	25.0	8.0	4.1	10.0
	Center	24.9	5.0	5.4	26.5
	West	24.9	4.0	4.9	17.0
8 August	East	21.5	0.0	6.7	14.0
	Center	19.8	0.0	6.4	27.0
	West	20.0	0.0	6.1	18.5

Table 2. Species collected on three different types of wood substrates during experiment 1 and their relative abundances (mean number/m^2 ± standard error of the mean). Surface areas: debarked logs, 0.081 m^2; barked logs, 0.88 m^2; dowel bundles, 0.174 m^2.

Species	Debarked logs	Barked logs	Dowel bundles
Ephemeroptera			
Caenis sp.	0.0 ± 0.0	17.1 ± 5.7	0.0 ± 0.0
Stenonema interpunctatum	62.0 ± 37.2	113.8 ± 11.4	69.0 ± 0.001
Stenonema pulchellum	6.2 ± 6.2	0.0 ± 0.0	8.6 ± 2.9
Stenonema sp. B	0.0 ± 0.0	5.7 ± 5.7	2.9 ± 2.9
Tricorythodes sp.	37.2 ± 24.8	187.7 ± 51.2	89.1 ± 48.9
Plecoptera			
Perlesta placida	0.0 ± 0.0	0.0 ± 0.0	2.9 ± 2.9
Trichoptera			
Nectopsyche candida (L)	0.0 ± 0.0	0.0 ± 0.0	2.9 ± 2.9
Nectopsyche sp. (P)	0.0 ± 0.0	5.7 ± 5.7	2.9 ± 2.9
Pycnopsyche sp. (L)	0.0 ± 0.0	5.7 ± 5.7	0.0 ± 0.0
Hydroptilidae (P)	0.0 ± 0.0	0.0 ± 0.0	2.9 ± 2.9
Coleoptera			
Berosus perigrinus (A)	6.2 ± 6.2	11.4 ± 11.4	0.0 ± 0.0
Macronychus glabratus (L)	24.8 ± 24.8	62.6 ± 62.6	97.8 ± 34.5
Helodidae (L)	0.0 ± 0.0	0.0 ± 0.0	2.9 ± 2.9
Diptera			
Atherix sp.	6.2 ± 6.2	0.0 ± 0.0	0.0 ± 0.0
Palpomyiia sp.	0.0 ± 0.0	0.0 ± 0.0	2.9 ± 2.9
Pentaneurini sp.	11.5 ± 24.8	130.8 ± 5.7	110.6 ± 8.6
Forcipimylinae sp.	6.2 ± 6.2	0.0 ± 0.0	28.8 ± 28.8
Empididae sp.	6.2 ± 6.2	0.0 ± 0.0	2.9 ± 2.9
Odonata			
Argia violacea	6.2 ± 6.2	11.4 ± 11.4	5.8 ± 5.8

Note: (L) = larvae; (P) = pupae; (A) = adults

Table 3. Numbers/m^2 (± S.D.) of taxa by time and substrate type within the Sangamon River during experiment 2.

Day:	7		14		21	
Substrate:	LOGS	DOWELS	LOGS	DOWELS	LOGS	DOWELS
Ephemeroptera						
Caenis sp.	22.7 (30.24)	21.0 (20.07)	49.3 (85.45)	21.3 (27.23)	3.7 (6.35)	67.0 (20.07)
Centroptillum sp.		7.7 (13.28)	3.7 (60.5)		3.7 (6.35)	5.7 (9.81)
Isonychia sp.				2.0 (3.46)		2.0 (3.46)
Potamanthus sp.	3.7 (6.35)			4.0 (6.93)	3.7 (6.35)	9.7 (16.74)
Stenonema interpunctatum	64.3 (73.36)	73.0 (48.59)	37.7 (28.68)	95.7 (54.63)	115.0 (66.20)	
Stenonema pulchellum	102.3 (102.50)	172.7 (197.63)	95.0 (82.46)	270.3 (276.17)	136.3 (70.78)	394.7 (371.30)
Tricorythodes sp.	91.0 (80.00)	46.0 (26.51)	201.0 (86.50)	71.0 (39.15)	292.0 (88.64)	157.3 (71.00)
Plecoptera						
Perlesta placida		6.0 (6.0)		13.7 (13.28)		21.0 (11.53)
Trichoptera						
Nectopsyche candida	3.7 (6.35)		19.0 (32.91)		3.7 (6.35)	5.7 (9.81)
Nectopsyche diarina			3.7 (6.35)			2.0 (3.46)
Potamyia flava				2.0 (3.46)	11.3 (11.50)	
Pycnopsyche sp.	3.7 (6.35)					
Coleoptera						
Macronychus glabratus	76.0 (62.64)	38.3 (29.26)	94.7 (85.93)	71.0 (49.03)	121.3 (75.87)	71.0 (27.40)
Odonata						
Argia violacea	3.7 (6.35)		7.3 (6.35)	4.0 (3.46)		

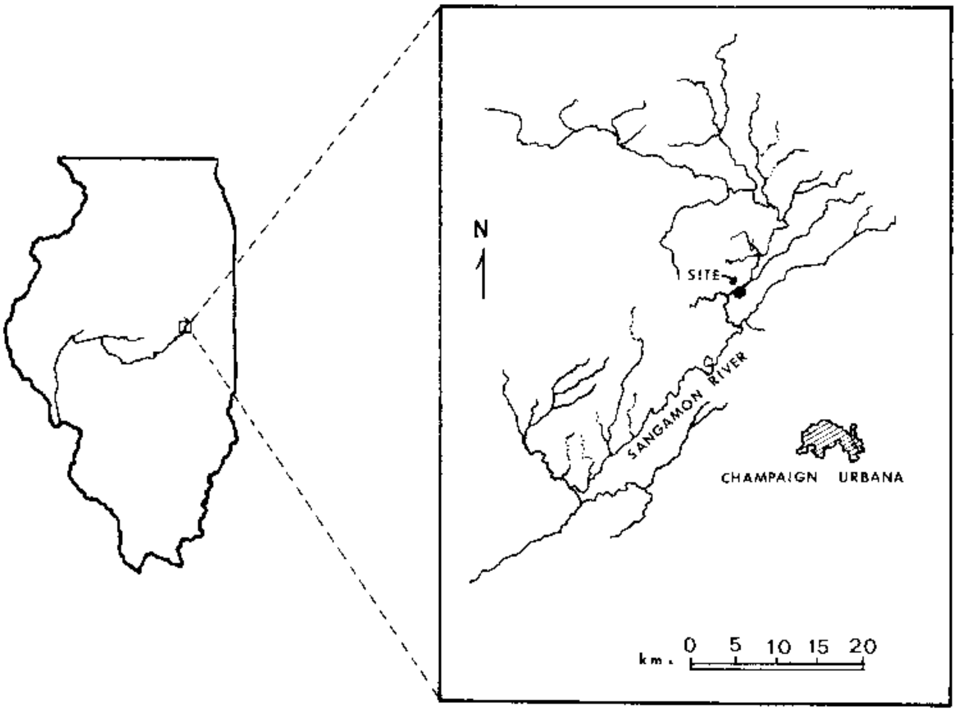
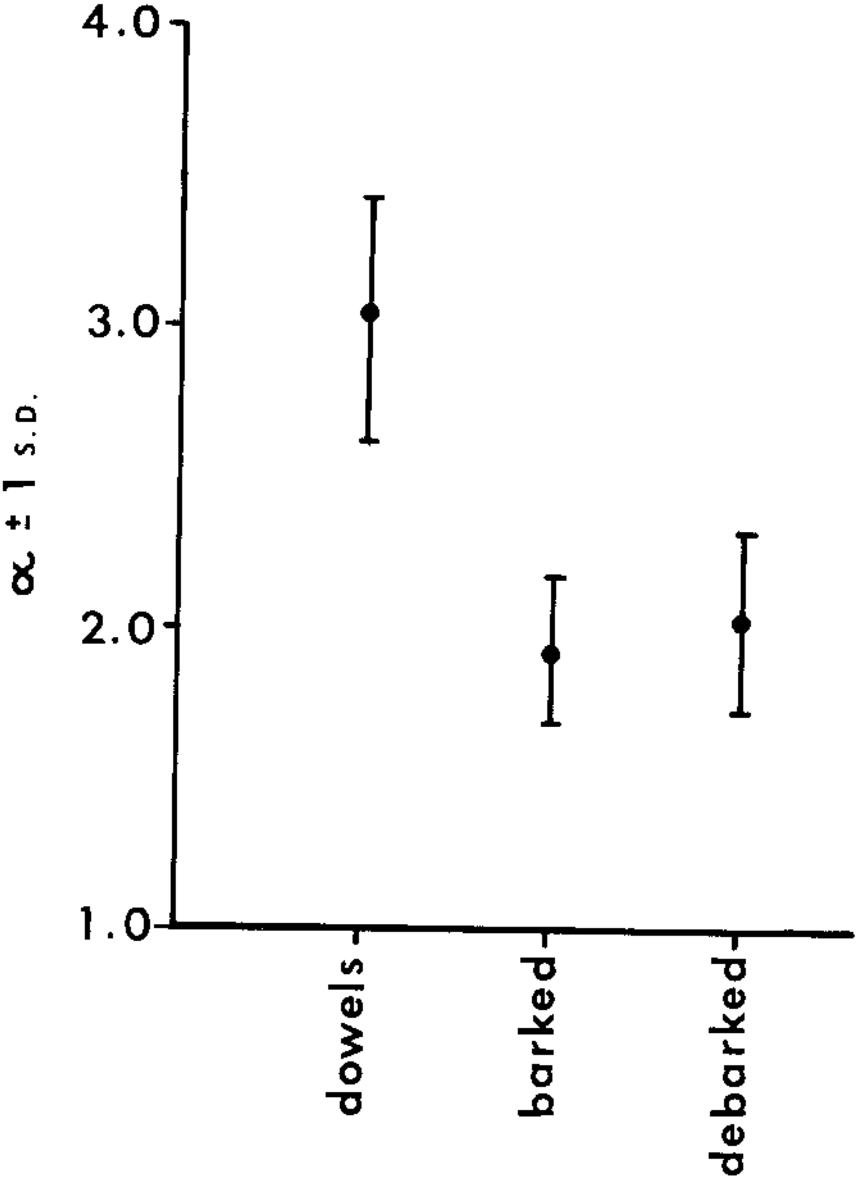
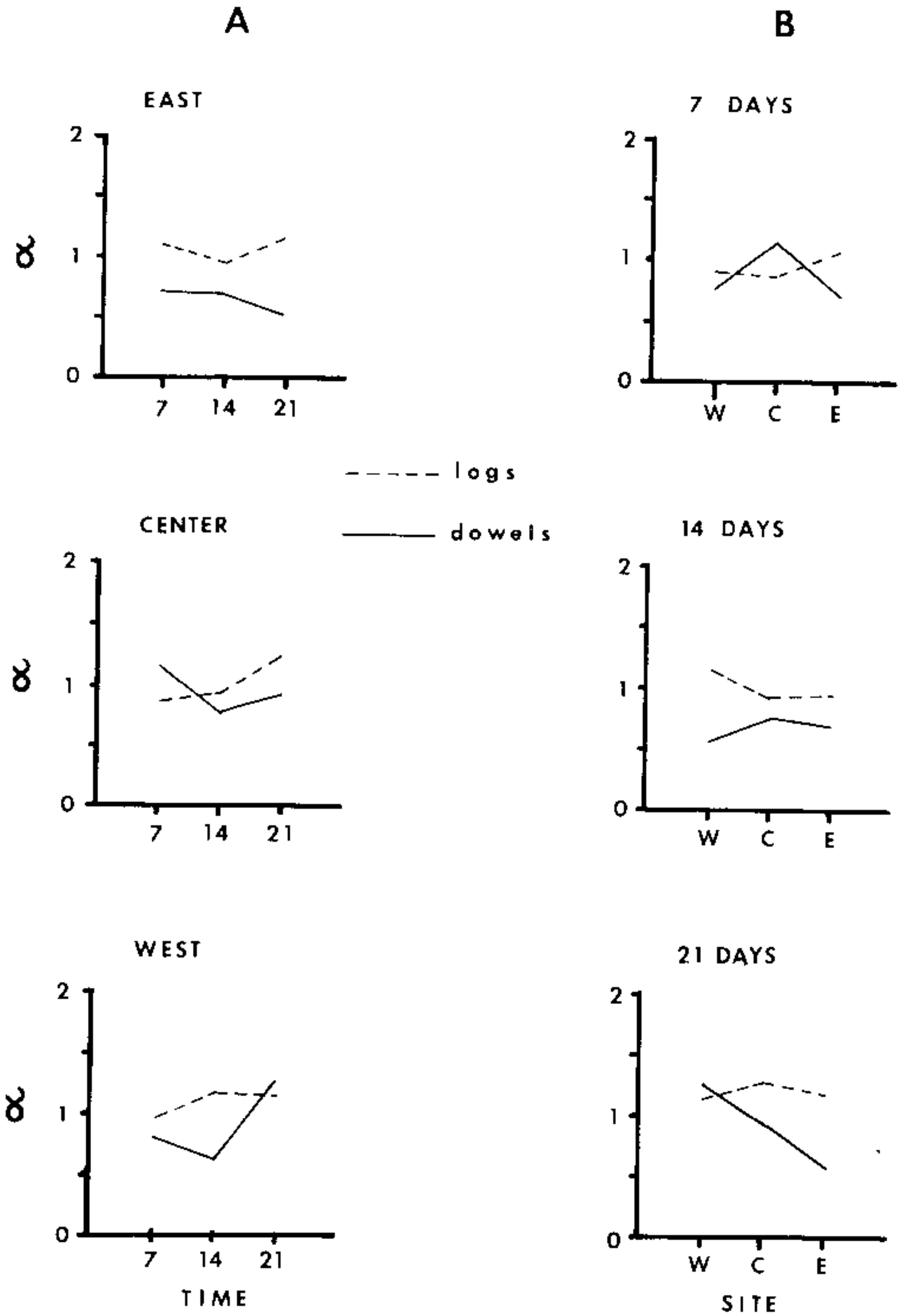


Figure legends

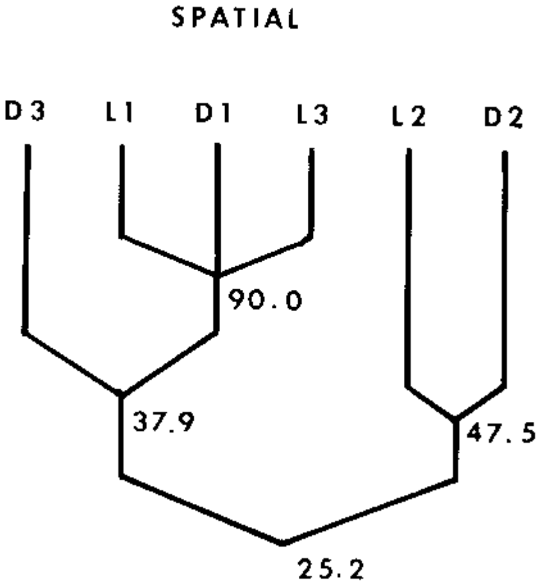
1. Location of study area in upper reaches of the Sangamon River, Illinois, in relation to the cities of Champaign-Urbana.

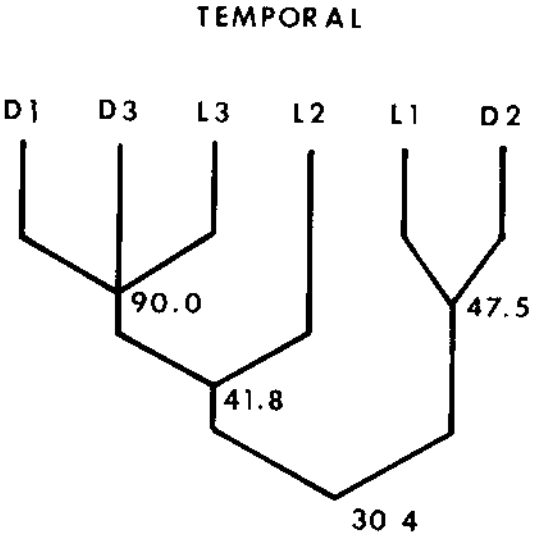


2. Community structure summary parameter of the logseries distribution (mean ± 1 standard deviation) for the three types of substrates allowed to colonize for 31 days in experiment 1.



3. Community structure summary parameters for both log and dowel bundle substrates in experiment 2: a) temporal change by site; b) spatial change by time.





4. Cluster dendrograms of communities colonizing substrates during experiment 2 arranged both spatially and temporally. D = dowel bundles, L = logs; numbers refer to sites: 1 = east bank; 2 = west bank; 3 = center channel.